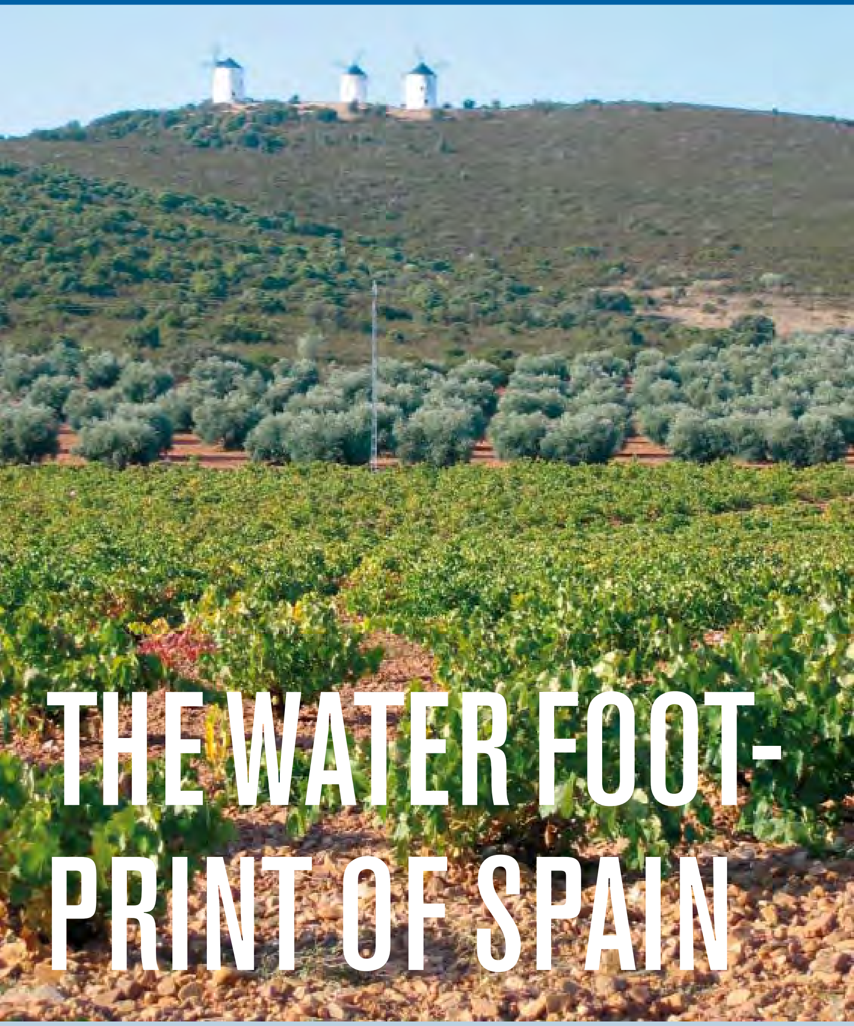

◀ *Figure 1:*
VINEYARDS AND OLIVE TREES IN LA MANCHA
Source: Zorrilla, 2008

THE WATER FOOTPRINT OF SPAIN

By MAITE MARTINEZ ALDAYA, A. GARRIDO, M.R. LLAMAS, C. VARELA-ORTEGA, P. NOVO and R. RODRÍGUEZ*

In most arid and semi-arid countries, water resource management is both an important and controversial issue. Today most water resource experts admit that water conflicts are not caused by the physical scarcity but they are mainly due to poor water management. The scientific and technological advances that occurred in the last fifty years open new paths to solving many water-related conflicts, often with tools that a few decades ago seemed unthinkable [15, 16]. Along these lines, the estimation and analysis of the water footprint of Spain, both from a hydrological and economic perspective, is very useful to facilitate the efficient allocation of water and economic resources.

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medewerkers/aldaya/Maite%20Aldaya/index.html
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This analysis can provide a transparent and multidisciplinary framework for informing and optimising water policy decisions, contributing at the same time to the implementation of the EU Water Framework Directive (2000/60/EC), especially in its article 5 and for the preparation of the river basin management plans.

The water footprint (WF) is a consumption-based indicator of water use. The WF of an individual or community is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community. Closely linked to the concept of water footprint is the virtual water. The virtual water content of a product (a commodity, good or service) refers to the volume of water used in its production [11]. Building on this concept, virtual water 'trade' represents the amount of water embedded in traded products. International trade can save water globally if a water-intensive commodity is traded from an area where it is produced with high water productivity (resulting in products with low virtual-water content) to an area with lower water productivity. At national or regional level, a nation can preserve its domestic water resources by importing products instead of producing them domestically. This is particularly relevant to arid or semi-arid countries with scarce water resources such as is the case in Spain.

Apart from stressing its potential contribution to water savings, it is also important to establish whether the water used proceeds from rainwater evaporated during the production process (green water) or surface water and/or groundwater evaporated as a result of the

RÉSUMÉ:

L'EMPREINTE SUR L'EAU DE L'ESPAGNE

Maite Martinez Aldaya, A. Garrido, M. R. Llamas, C. Varela-Ortega, P. Novo et R. Rodríguez

En Espagne, le pays le plus aride de l'Union Européenne, la gestion des ressources en eau constitue un problème aussi important que controversé. Aujourd'hui, la majorité des experts en ressources en eau admettent que les conflits relatifs à l'eau ne sont pas provoqués par la rareté physique de l'eau, mais qu'ils sont dus principalement à une mauvaise gestion de l'eau. Le concept d'eau virtuel, défini comme le volume d'eau utilisé dans la production d'une denrée, d'un bien ou d'un service ainsi que l'empreinte sur l'eau (volume d'eau utilisé pour produire les biens et services consommés par une personne ou une communauté), englobent conjointement une vaste gamme de secteurs et de problèmes, fournissant ainsi un cadre adéquat pour trouver des solutions potentielles et pour contribuer à une meilleure gestion des ressources en eau, notamment dans des pays arides ou semi-arides comme l'Espagne.

▲ *Figure 2:*
PIVOT IRRIGATION IN THE UPPER GUADIANA BASIN
Source: NeWater

production of the product (blue water) [7]. Traditionally, emphasis has been given to the concept of blue water through the "miracle" of irrigation systems. However, an increasing number of authors highlight the importance of green water [3, 5, 8]. The economic and hydrological assessment of the water footprint and virtual water of both green and blue water (considering surface and groundwater) of the different economic sectors could facilitate a more efficient allocation and use of water resources, providing simultaneously a transparent interdisciplinary framework for policy formulation.

	Spain	Italy	US	India
Population (10^6)	40.5	57.7	280.3	1007.4
Urban water supply				
km^3/year	4.2	8.0	60.8	38.6
m^3/cap/year	105.0	136.0	217.0	38.0
Crop evapotranspiration				
National consumption (km^3/year)	50.6	47.8	334.2	913.7
Idem (m^3/cap/year)	1251.0	829.0	1192.0	907.0
For export (km^3/year)	17.4	12.4	139.0	35.3
Idem (m^3/cap/year)	430.0	214.0	495.0	35.0
Industrial uses				
National use (km^3/year)	5.6	10.1	170.8	19.1
Idem (m^3/cap/year)	138.0	176.0	609.0	14.0
For export (km^3/year)	1.7	5.6	44.7	19.1
Idem (m^3/cap/year)	42.0	97.0	159.0	6.0
Virtual water 'import'				
Agricultural products (km3/year)	27.1	60.0	74.9	13.8
Idem (m^3/cap/year)	671.0	1039.0	267.0	14.0
Industrial products (km^3/year)	6.5	8.7	56.3	2.2
Idem (m^3/cap/year)	1605.0	150.8	208.9	21.8
Re-export of imported products	11.4	20.3	45.6	1.2
Idem (m^3/cap/year)	281.0	351.0	163.0	1.0
TOTAL WATER FOOTPRINT				
km^3/year	94.0	134.6	896.0	987.4
m^3/cap/year	2300.0	2300.0	2500.0	980.0

◀ *Table 1:*
VIRTUAL WATER FLOWS AND WATER FOOTPRINT OF SPAIN, ITALY, US AND INDIA (PERIOD 1997 – 2001)
Source: Modified from [3] in [7]

OVERVIEW OF SPAIN'S DIFFERENT SECTORS

Spain is the most arid country of the European Union and the one that devotes most water resources to irrigation [17]. According to Chapagain and Hoekstra (2004), total water requirements (green and blue) by the different economic sectors in Spain are about 100 km^3/year, that are distributed as follows:

According to table 1, **urban water supply** represents 5% of the total water used with a value of 4,200 million euros [17].

The **industrial sector** amounts to 15% of the total water use (from which more than a half corresponds to virtual water 'imports'), 14% of the Gross Domestic Product (GDP) (123,000 million euros, [6]) and 16% of the economically active population (3,100,000 jobs, [6]) (table 2).

Urban water supply and industrial sector figures refer to blue water uses and are in line with the values given by official statistics [17]. Frequently the data from the MIMAM does not consider the consumptive uses, typical of agricultural, but the total water supplied; and usually a certain amount of this water returns downstream to the river basin and can available to downstream users.

The **agricultural sector**, considering green and blue crop consumption and livestock water use, represents about 80% of the total water use in line with [6] (2/3 with national water and 1/3 with 'imported' virtual water) (table 1) and [19]. The agricultural sector, however, just contributes with about 3% of the Gross Domestic Product (GDP) (about 26,000 million euros, including livestock and fisheries, according to [14]) and employs 5% of the economically active population (1,050,000 jobs, following [14]) (table 2). Special emphasis is given to this sector, as it is by far the main water user in Spain.

WATER FOOTPRINT OF AGRICULTURE

Concerning the crop water consumptive use of agriculture in Spain, there are remarkable differences between the results of the different authors (table 3). Official numbers from the Spanish Ministry of the Environment are the lowest [17], probably due to the fact that official numbers do not take into account green water. Incorporating the concept of green water into the bigger picture makes it possible to understand water implications of land cover change and water scarcity problems of rain-fed agriculture [8]. In order to achieve an effective land use planning, green water analysis should be considered within an integrated land and water resource approach. Crop water consumptive use estimated by Chapagain and Hoekstra (2004) is higher than that of Rodríguez (2008) probably because of the greater detail of the latest study.

	Gross Domestic Product		Employment	
	Million €	%	Thousand jobs	%
Agriculture, livestock and fishing	26,473	3	1,033	5
Energy	20,415	2	149	1
Industry	122,844	14	3,130	16
Building industry	94,161	10	2,425	12
Services sector	546,929	60	13,324	66
Total	905,455	100	20,061	100

▲ *Table 2:*
GROSS DOMESTIC PRODUCT AND EMPLOYMENT IN SPAIN, YEAR 2005 AT CURRENT PRICES
Source: Modified from Novo (2008), based on INE (2008) data **[14]**

Within the agricultural sector, irrigated agriculture uses about 80% of blue water resources [13, 17]. Concerning the economic aspects, however, irrigated agriculture is a vital component of the agricultural sector. Even if it just occupies about 20% of total crop area, it produces 60% of the total Gross Value Added (GVA) of agriculture [17]. This benefit is higher than the global average. Worldwide the gross value of rain-fed agriculture is 55% amounting to 72% of the world's harvested cropland [5]. Along these lines, the economic productivity (Euro/ha) in irrigated agriculture in Spain is about five times higher than that of rain-fed agriculture [4, 10, 17].

EFFICIENT ALLOCATION OF WATER RESOURCES

Spanish agriculture has comparative advantages as a result of its soil availability, sunshine hours, reasonable labour costs and location in relation to markets. Spain has no barriers to trade with other EU Member States. On the whole, Spain benefits from this advantage producing high value crops adapted to the Mediterranean climate, such as vegetables, citrus trees, vineyards and olive trees (figure 3).

First of all, it has to be highlighted that rain-fed grain cereals in Spain occupy more than 5 million hectares as shown in figure 3. In the year 2001, grain cereals were the main land and water users in Spain, utilizing the 47% of total arable land and 32% of blue water resources (figures 3 and 5) [17]. In economic terms, however, they generated the lowest GVA value, which was about 6% GVA of irrigated agriculture according to MIMAM data [17]. Nevertheless, we cannot just focus on economic aspects and forget the importance of agricultural multi-functionality (economic, social and environmental).

On the other hand, vegetables, citrus trees and fruit trees are very productive in economic terms and require a relatively small amount of land and water. These are, however, mainly grown with blue water resources. The best opportunities and economic yields are obtained when these are grown in areas where blue water resources are less abundant. In addition, carbon-intensive agro-chemical doses used in irrigated agriculture are higher than those used in rain-fed agriculture, with the corresponding ecologic impact [17]. Blue wa-

▼ *Figure 3:*
TOTAL AREA (ha) PER CROP (Mha), TOTAL GROSS VALUE ADDED (GVA) (M€) AND TOTAL SUBSIDIES (M€) COMPARING RAIN-FED AND IRRIGATED AGRICULTURE IN SPAIN FOR THE YEAR 2001.
Source: based on data from the Spanish Ministry for the Environment **[17]**

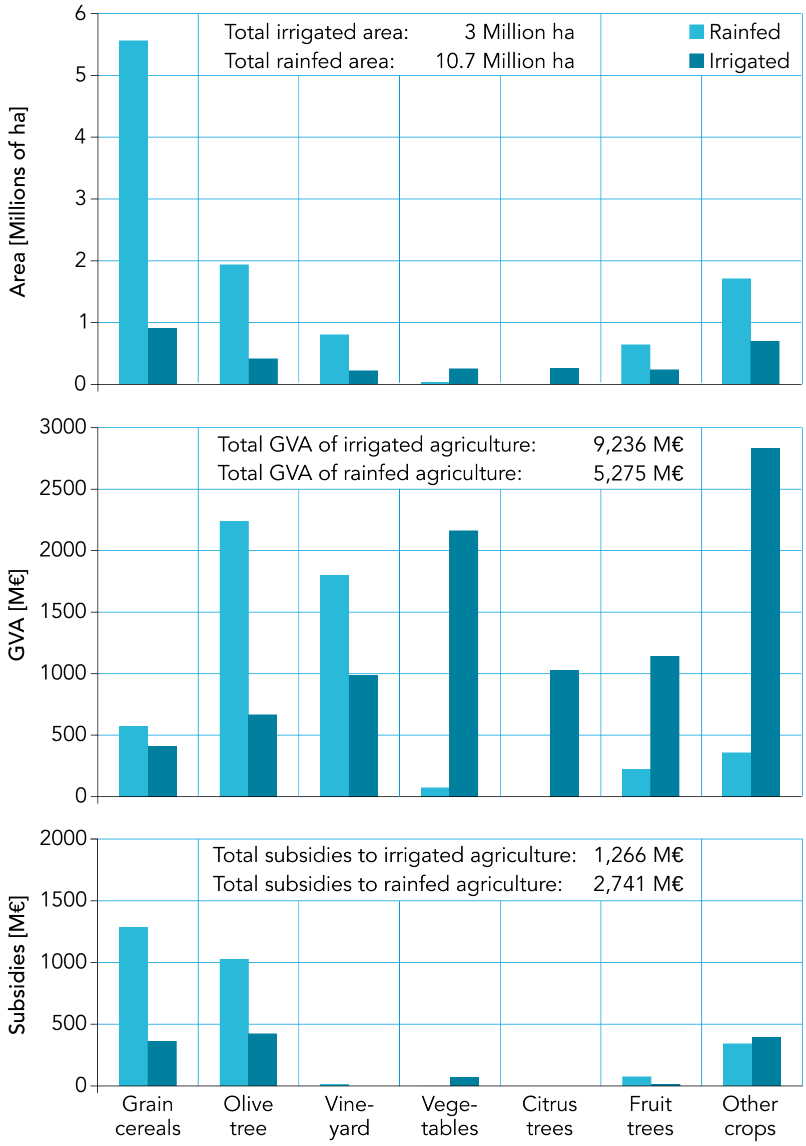
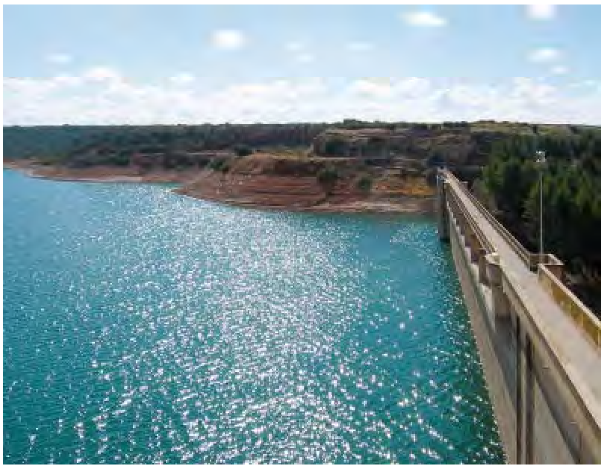
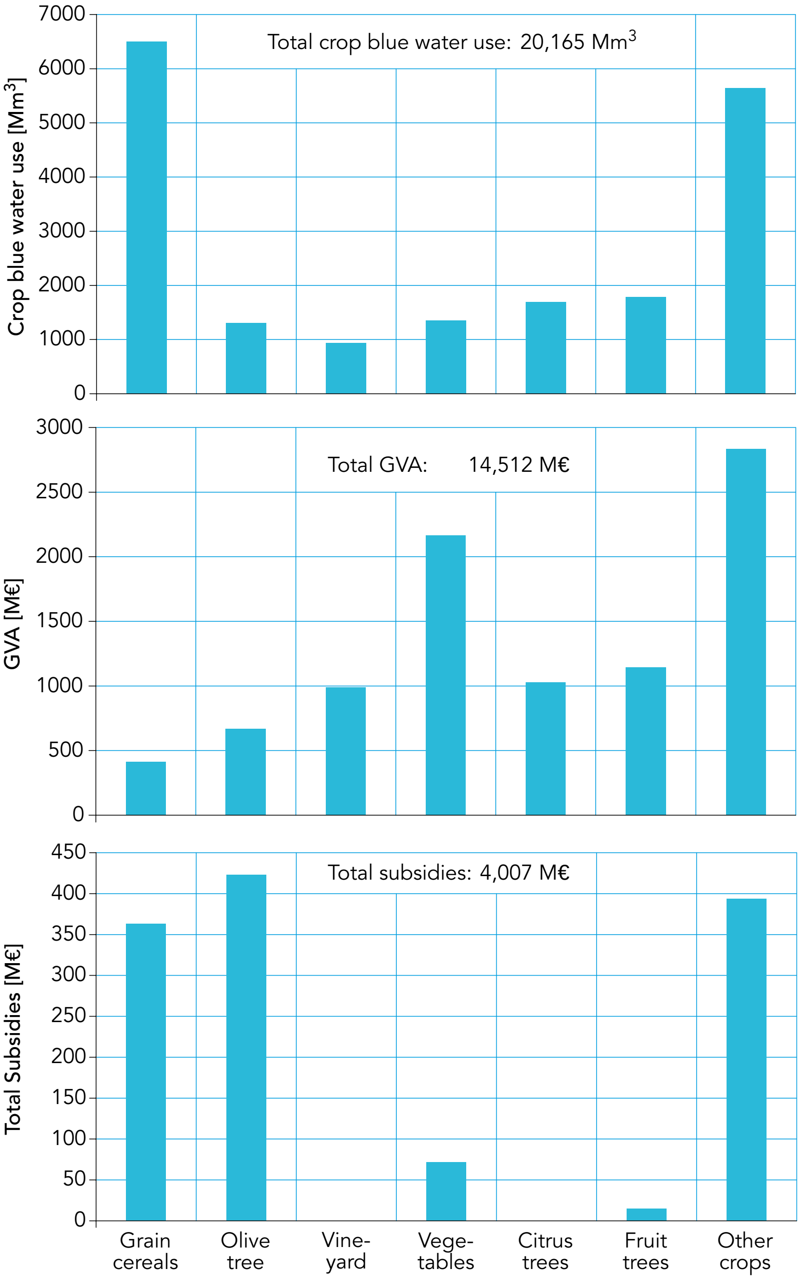


Table 3: **ESTIMATED VALUES OF INTERNAL OR DOMESTIC WATER CONSUMPTIVE USE IN SPAIN'S AGRICULTURAL CROP PRODUCTION AFTER DIFFERENT SOURCES:**	Agricultural water consumption[1] (Mm³)	Blue water consumption[2] (Mm³)	Green water consumption[3] (Mm³)
MIMAM (2007)[4]	-	11,897	-
Chapagain and Hoesktra (2004)[5]	50,570	-	-
Rodríguez (2008)[6]	26,824	15,645	11,177

1 Agricultural water consumption refers to the total crop water evapotranspiration.
2 Blue water consumption is the total amount of irrigation water evapotranspirated by the crops.
3 Green water consumption represents the total amount of soil water evapotranspirated by crops.
4 Average figures for the year 2001 (average rainfall year).
5 Average figures for the period 1997-2001
6 Average figures for the years 1998, 2001 and 2003.



▶ *Figure 4:*
PEÑARROYA DAM IN CIUDAD REAL
Source: Zorrila



▲ *Figure 5:*
CROP BLUE WATER SUPPLY (Mm^3), TOTAL GROSS VALUE ADDED (GVA) (M€) AND TOTAL SUBSIDIES (M€) TO IRRIGATED AGRICULTURE IN SPAIN FOR THE YEAR 2001.
Source: based on MIMAM data **[17]**

ter use in Spain, thus, has generally a higher opportunity cost and greater negative environmental externalities than green water use.

The water apparent productivity analysis can be very useful in order to identify possible water uses not justified in economic efficiency terms and achieve an efficient allocation of water resources. According to **MIMAM (2007)**, average productivity of blue water used in irrigated agriculture is about 0.44 €/m^3. When looking at the productivity per crop type (**figure 6**), greenhouse crops (horticultural, flowers and ornamental plants) present the highest Gross Value Added per water unit (with a minimum 4.87 €/m^3 and a maximum 17.52 €/m^3). With lower values vegetables, vineyards and temperate climate trees show intermediate values. Finally, with remarkably lower values, grain cereals display an average productivity of just 0.06 €/m^3. Accordingly, the apparent productivity of greenhouse crops is about one hundred times higher than that of cereals.

Figure 7 shows that a mere 4% of all blue water used in irrigated agriculture accounts for 66% of the total value added. Conversely, close to 60% of the water used in this sector produces a slight 5% of total value added in agriculture. Along these lines, even if Spain has already achieved a good degree of the policy "more crops and jobs per drop", it struggles to obtain "more cash and nature per drop" **[2]**.

Even if not considered in the study of **[17]**, most probably high value crops are watered with groundwater resources or a combination of ground and surface water **[9, 15]**. This difference can be attributed to several causes: the greater control and supply guarantee that groundwater provides, which in turn allows farmers to introduce more efficient irrigation techniques and more profitable crops; the greater dynamism that has characterized the farmer that has sought out his own sources of water and bears the full costs of drilling, pumping and distribution; and the fact that the higher financial costs farmers bear motivates them to look for more profitable crops that will allow them to maximize their return on investments **[9]**. Surface and groundwater distinction, therefore, should be taken into account in order to achieve an efficient allocation of water resources.

VIRTUAL WATER 'TRADE' IN SPAIN

Agricultural commodity trade in relation to water is an issue that has rarely been dealt with. It is important to take into account that Spain is a net virtual water 'importer' concerning agricultural commodities. According to **Chapagain and Hoekstra (2004)** Spain 'imports' about 27 km^3/year and 'exports' 17 km^3/year, resulting in a negative balance of 10 km^3/year. Spain exports high economic value and low virtual water content crops, such as citrus fruits, vegetables or olive oil, while it exports virtual water intensive and low-economic value crops, such as cereals **[18, 19]**. This not only has a huge potential for relieving local hydrologic, economic and political stress in Spain but it is also very relevant for the national economy and water balance. Cereal grains can thus be crucial commodities in terms of importance for food security to water-scarce importing and developing countries [21]. Spain's cereals production is only 5% of the total EU's, so Spanish demand would always be supplied by other EU producers or security stocks. This, however, does not imply that importing food is the only response the water-scarce countries and regions should and can take [22]. Furthermore, in the real world, even if the potential of trade to 'save' water at national level is substantial, most international food trade occurs for reasons not related to water resources [5]. International trade in agricultural commodities mainly depends on factors such as the availability of land, labour, technology, the costs of engaging in trade, freight costs, national food policies and international trade agreements [1, 12].

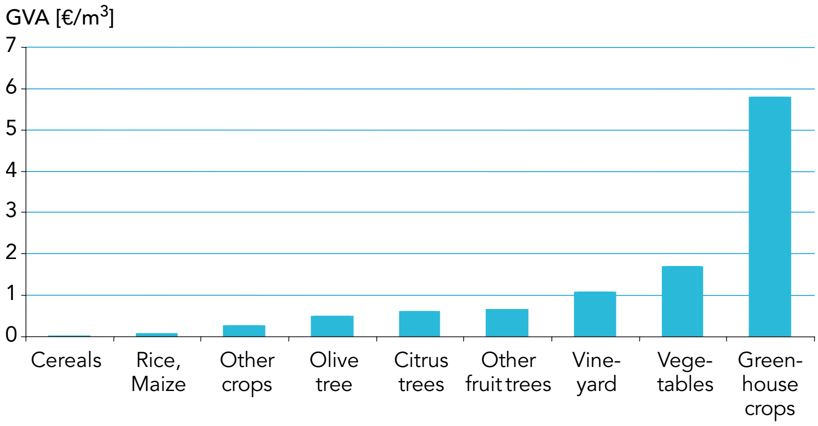
Spain's cereal imports make up about 70% of all water agricultural imports, whereas livestock exports represent 55% [19]. Both are obviously linked and respond to Spanish natural endowments, land and climate, and its intimate integration in the EU economy. Water scarcity as such does not explain why Spain 'exports' virtual water through livestock products. Lesser enforcement of environmental legislation, more empty territory and a great deal of economic integration do more to explain it. However, clearly without the option to import cereals and feedstock, the livestock sector would not have grown to the extent it did in the last 10 years.

CONCLUSION

In conclusion, water scarcity in Spain is mainly due to the inefficient allocation of water resources and mismanagement in the agricultural sector, such as the use of large amounts of blue water in virtual water intensive but low economic value crops. Nevertheless, the Spanish water footprint should be analysed in time and from the point of view of sectorial and geographical standpoints. Furthermore, we cannot forget the multifunctionality of agriculture.

On the whole, there seems to be enough water to satisfy the Spanish agricultural sector needs, but a necessary condition is to achieve an efficient allocation and management of water resources. This will take some time since crop distribution in Spain is determined by several factors such as the CAP or the WTO regulations. The mentioned transition will require the action of the Spanish Government by embracing transparency and encouraging an active and effective public participation. This is already happening in Spain on the occasion of the application of the WFD.

The water footprint analysis, both hydrological and economic, at a river basin level facilitates the efficient allocation of water resources to the different economic and ecologic demands. There is no blueprint. The Spanish context is characterized by regional differences on green and blue water resource availability. Along these lines, virtual water studies, taking into account not only green and blue (ground and surface) water systems but also trade policies, can contribute to the better integrated management of water resources.



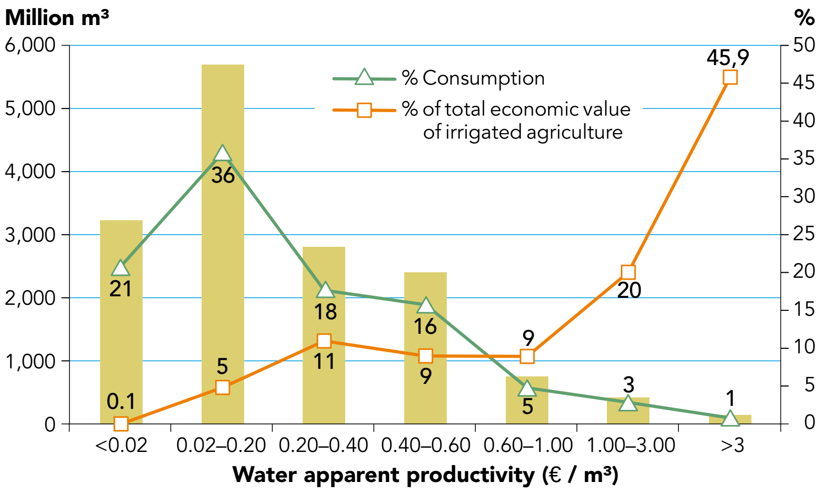
▲ *Figure 6:*
WATER APPARENT PRODUCTIVITY (GROSS VALUE ADDED PER CUBIC METRE – GVA/m³) PER CROP IN IRRIGATED AGRICULTURE IN SPAIN FOR THE YEAR 2001 – 2002. DATA FOR 78% OF THE IRRIGATED AREA.
Source: based on MIMAM data **[17]**

Finally, this analysis, in industrialized countries such as Spain can help to move from a policy of 'more crops and jobs per drop' towards 'more cash and nature per drop'. Achieving, thus, the preservation of the environment without damaging the agricultural sector economy.

ABSTRACT:

As the most arid country in the European Union, water resource management in Spain is an issue as important as controversial. Today most water resources experts admit that water conflicts are not caused by the physical water scarcity but they are mainly due to poor water management. The virtual water concept, defined as the volume of water used in the production of a commodity, good or service, together with the water footprint (water volume used to produce the goods and services consumed by a person or community), link a large range of sectors and issues, providing an appropriate framework to find potential solutions and contribute to a better management of water resources, particularly in arid or semi-arid countries such as Spain.

▼ *Figure 7:*
TOTAL WATER USE IN AGRICULTURE BY CROP PRODUCTIVITY RANGE AS PERCENT OF VOLUME AND VALUE ADDED (BASED ON 78% OF TOTAL IRRIGATION IN SPAIN) (2001-2002).
Source: Varela-Ortega (2008), based on data of **[17]**



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▲ *Figure 8:* **TABLAS DE DAIMIEL NATIONAL PARK IN THE SOUTH-CENTRAL SPAIN**
Source: Martínez-Santos, 2008

The Tablas de Daimiel National Park, located in south-central Spain, is a wetland on the list of the Ramsar Convention and part of the Mancha Húmeda Biosphere reserve. Today, however, this wetland that used to receive the natural discharge from the Occidental Mancha aquifer, survive artificially, in a kind of "ecological coma", thanks to the water transfers that come from the Tagus-Segura Aqueduct and to the artificial pumpage of groundwater.

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